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ABSTRACT

Reports from the Third International Mathematics and Science Study (TIMSS) provide a starting point from which to examine U.S. student achievement in mathematics and science in an international context. This publication illustrates how the different types of information found in the international reports can provide a springboard for in-depth reflection on the strengths and weaknesses of educational efforts in the United States at the national, state, and local levels. By highlighting some of the eighth-grade findings from TIMSS, this booklet aims to help readers better understand how TIMSS can serve as a tool for education reform. Policymakers and educators can compare the findings of TIMSS with local student performance and educational practices in order to facilitate reform initiatives. Contents include: "U.S. Achievement in International Context"; "Improving Thoughtful Problem Solving in Mathematics"; "Improving Scientific Understanding"; and "School Contexts for Learning." (AIM)

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BENCHMARKING TO INTERNATIONAL ACHIEVEMENT

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TIMSS AS A STARTING POINT TO EXAMINE STUDENT ACHIEVEMENT

BENCHMARKING TO INTERNATIONAL ACHIEVEMENT

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Thomas Hoffmann did the layout and graphics for this booklet. We also wish to acknowledge the help of several individuals who reviewed this document and provided valuable suggestions for its improvement. We thank Albert E. Beaton of Boston College, Pat O'Connell Ross and colleagues of the Office of Reform Assistance and Dissemination, Eugene Owen and Lois Peak of the National Center for Education Statistics (NCES), and Patrick Gonzales of the Education Statistics Services Institute (ESSI). Thanks also to Rima Azzam and colleagues at the Pelavin Research Institute for coordination and editing, Cynthia Hearn Dorfman and colleagues in Media and Information Services, and Ruth Chacon and colleagues at The Widmeyer-Baker Group for production of this document.

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Introduction

The reports of the Third International Mathematics and Science Study (TIMSS) provide a starting point to examine U.S. student achievement in an international context. *Mathematics Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study* and *Science Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study* summarize mathematics and science achievement for seventh and eighth graders in 41 countries around the world. They are included in this module of the TIMSS Resource Kit. Another report that focuses primarily on U.S. findings for the middle school years, *Pursuing Excellence: A Study of U.S. Eighth-Grade Mathematics and Science Teaching, Learning, Curriculum, and Achievement in International Context,* is also available in the first module of this Resource Kit, *Attaining Excellence: TIMSS as a Starting Point to Examine U.S. Education.*

The TIMSS reports containing results for seventh and eighth graders represent the first in a series. Ordering information for the two corresponding publications presenting the mathematics and science results for third and fourth graders can be found on the last page of this booklet. TIMSS results for students in the final year of secondary school will be available in spring 1998.

The data in these international reports provide a wealth of information about achievement and instructional practices in the United States as compared with other countries. For example, overall national performance is examined in light of students' responses to individual test questions. The reports also include information about selected curriculum, teacher, classroom, and home factors.

This booklet illustrates how the different types of information found in the international reports can provide a crucial springboard for in-depth reflection about the strengths and weaknesses of education efforts in the United States, at the national, state, and local levels.

By highlighting some of the eighth-grade findings from TIMSS, this booklet aims to help readers better understand how TIMSS can serve as a tool for education reform. Policymakers and educators can compare the findings of TIMSS with local student performance and educational practices in order to facilitate reform initiatives.

About TIMSS...

TIMSS is the largest and most ambitious study of comparative educational achievement ever undertaken. In total, TIMSS achievement testing in mathematics and science involved:

- more than 40 countries;
- 5 grade levels (3rd, 4th, 7th, 8th, and 12th);
- more than a half-million students;
- testing in more than 30 languages;
- more than 15,000 participating schools;
- millions of written responses to open-ended questions;
- performance assessment; and
- student, teacher, and school questionnaires about the contexts for schooling.

TIMSS was conducted with attention to quality at every step of the way. Rigorous procedures were designed to translate the tests, and numerous regional training sessions were held in data collection and scoring procedures. Quality-control observers monitored testing sessions. The procedures for sampling the students tested in each country were scrutinized according to rigorous standards designed to maximize inclusion, prevent bias, and ensure comparability.

TIMSS is the most recent in a series of studies conducted by the International Association for the Evaluation of Educational Achievement (IEA). The IEA has been providing comparative information about educational achievement and learning contexts to policymakers, educators, researchers, and practitioners since 1959. The International Study Center for TIMSS is located at Boston College. International activities are funded by the National Center for Education Statistics (NCES) of the U.S. Department of Education and the U.S. National Science Foundation (NSF). Each country provides its own funding for the national implementation of TIMSS. In the United States, TIMSS was also funded by NCES and NSF.

U.S. Achievement in International Context

The technological and economic contexts of our world are undergoing rapid changes. Because education is central in preparing individuals and nations to take the best advantage of these changes, information about excellence in academic achievement has become increasingly important. International comparative studies provide empirical data about the quality of a nation's educational system as viewed from the perspective of the global community.

For example, recent results from the National Assessment of Educational Progress (NAEP) show improvements since 1990 in mathematics achievement at all three grades tested: 4, 8, and 12. This is good news indeed. One of our national goals is to be "first in the world in mathematics and science achievement by the year 2000," as President Bush and 50 governors declared in 1989. The TIMSS results for fourth-grade students show promise toward reaching this goal. In science, students in only one country outperform U.S. fourth graders—Korea. In mathematics, U.S. fourth graders score above the international average; but students in seven countries—Singapore, Korea, Japan, Hong Kong, Netherlands, Czech Republic, and Austria—outperform U.S. fourth graders.

Despite these encouraging signs for education in the United States, the TIMSS results for eighth graders show that we have a long way to go to fully reach our goal (see Table 1). Compared to the other countries participating in TIMSS, the relative performance of U.S. eighth graders was well below that of U.S. fourth graders. Even though the average achievement of U.S. eighth graders resembles that of other major industrialized nations like Canada, England, and Germany, by and large, the international performance standards in middle school mathematics and science are being set by Singapore, Japan, and Korea. The TIMSS achievement results provide several interesting perspectives from which to view the overall performance of U.S. eighth graders compared with those of the top-performing countries.

- Besides top-performing Singapore, Korea, and Japan, Hong Kong also performs well in mathematics, as does Belgium (Flemish) and Czech Republic. In contrast, U.S. eighth graders score below the international average of the 41 TIMSS countries. In no other

MATHEMATICS

NATIONS WITH AVERAGE SCORES SIGNIFICANTLY HIGHER THAN THE U.S	
NATION	**AVERAGE**
SINGAPORE	643
KOREA	607
JAPAN	605
HONG KONG	588
BELGIUM-FLEMISH	565
CZECH REPUBLIC	564
SLOVAK REPUBLIC	547
SWITZERLAND	545
(NETHERLANDS)	541
(SLOVENIA)	541
(BULGARIA)	540
(AUSTRIA)	539
FRANCE	538
HUNGARY	537
RUSSIAN FEDERATION	535
(AUSTRALIA)	530
IRELAND	527
CANADA	527
(BELGIUM-FRENCH)	526
SWEDEN	519
NATIONS WITH AVERAGE SCORES NOT SIGNIFICANTLY DIFFERENT FROM THE U.S	
(THAILAND)	522
(ISRAEL)	522
(GERMANY)	509
NEW ZEALAND	508
ENGLAND	506
NORWAY	503
(DENMARK)	502
UNITED STATES	**500**
(SCOTLAND)	498
LATVIA (LSS)	493
SPAIN	487
ICELAND	487
(GREECE)	484
(ROMANIA)	482
NATIONS WITH AVERAGE SCORES SIGNIFICANTLY LOWER THAN THE U.S	
LITHUANIA	477
CYPRUS	474
PORTUGAL	454
IRAN, ISLAMIC REPUBLIC	428
(KUWAIT)	392
(COLOMBIA)	385
(SOUTH AFRICA)	354

INTERNATIONAL AVERAGE = 513

SCIENCE

NATIONS WITH AVERAGE SCORES SIGNIFICANTLY HIGHER THAN THE U.S	
NATION	**AVERAGE**
SINGAPORE	607
CZECH REPUBLIC	574
JAPAN	571
KOREA	565
(BULGARIA)	565
(NETHERLANDS)	560
(SLOVENIA)	560
(AUSTRIA)	558
(HUNGARY)	554
NATIONS WITH AVERAGE SCORES NOT SIGNIFICANTLY DIFFERENT FROM THE U.S	
ENGLAND	552
BELGIUM-FLEMISH	550
(AUSTRALIA)	545
SLOVAK REPUBLIC	544
RUSSIAN FEDERATION	538
IRELAND	538
SWEDEN	535
UNITED STATES	**534**
(GERMANY)	531
CANADA	531
NORWAY	527
NEW ZEALAND	525
(THAILAND)	525
(ISRAEL)	524
HONG KONG	522
SWITZERLAND	522
(SCOTLAND)	517
NATIONS WITH AVERAGE SCORES SIGNIFICANTLY LOWER THAN THE U.S	
SPAIN	517
FRANCE	498
(GREECE)	497
ICELAND	494
(ROMANIA)	486
LATVIA (LSS)	485
PORTUGAL	480
(DENMARK)	478
LITHUANIA	476
BELGIUM-FRENCH	471
IRAN, ISLAMIC REPUBLIC	470
CYPRUS	463
(KUWAIT)	430
(COLOMBIA)	411
(SOUTH AFRICA)	326

INTERNATIONAL AVERAGE = 516

Table 1

Eighth-Grade Achievement in Mathematics and Science: Nations' Average Performance Compared to the United States*

Source:

IEA Third International Mathematics and Science Study (TIMSS), 1994-1995

*Eighth grade in most nations. Nations shown in parentheses did not satisfy one or more guidelines for sample participation rates, age/grade specifications, or classroom sampling procedures.

Latvia is annotated LSS for Latvian-Speaking Schools only.

The TIMSS international reports present standard errors for all survey estimates.

TIMSS country did mathematics performance drop from above average in the fourth grade to below average in the eighth grade.

- Eighth graders in Singapore, Korea, and Japan outperform those in the United States by more than 100 points on the TIMSS mathematics scale. This is a substantial difference, especially considering that the difference in performance between grades seven and eight is only 26 points in the United States.
- In science, U.S. eighth graders scored above the international average of the 41 TIMSS countries. Yet, in contrast to grade four, the United States is not one of the top-performing countries. Singapore is the top-performing country in this subject. Czech Republic, Japan, and Korea also perform among the best in the world.
- Singaporean eighth graders outscored those in the United States by 73 scale points in science. The U.S. increase between grades seven and eight was 47 scale points.
- If the top 10 percent of all eighth-grade students in the 41 TIMSS countries were to be considered as a group, 5 percent of the U.S. eighth-grade students would be included in mathematics. In science, 13 percent would be included. The corresponding figures for Singapore would be 45 percent in mathematics and 31 percent in science.

Although the TIMSS results are useful for monitoring our national goal in mathematics and science achievement, they go beyond the purpose of providing international standings. TIMSS also can provide valuable information about strengths and weaknesses within subject area achievement. At the eighth-grade level, TIMSS measures achievement in six content areas in mathematics and five areas in science.

- Compared to their overall performance in mathematics, nearly all countries do relatively better in several content areas than they do in others. The relative strengths of U.S. eighth graders are in Algebra; Fractions and Number Sense; and Data Representation, Analysis, and Probability. Relative weaknesses are in Geometry, Measurement, and Proportionality.
- Compared to their overall performance in science, eighth graders in the United States do better in Earth Science, Life Science, and Environmental Issues and the Nature of Science. The relative weaknesses are in Chemistry and Physics.

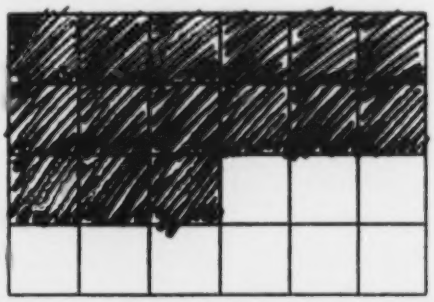
Considering the TIMSS results for clusters of individual test questions provides even more refined indications of needed emphases in classroom instruction. If students in the United States are to challenge those in the highest performing countries, then parents, teachers, administrators, school board members, and other policymakers must be well informed regarding what children know and can do in school mathematics and science, so that they can use this information to improve mathematics and science education.

HOW DO U.S. EIGHTH-GRADE STUDENTS COMPARE TO THE INTERNATIONAL AVERAGE IN...?

MATHEMATICS CONTENT AREAS:		SCIENCE CONTENT AREAS:	
DATA REPRESENTATION, ANALYSIS, AND PROBABILITY	ABOVE	EARTH SCIENCE	ABOVE
FRACTIONS AND NUMBER SENSE	SAME	LIFE SCIENCE	ABOVE
ALGEBRA	SAME	ENVIRONMENTAL ISSUES AND THE NATURE OF SCIENCE	ABOVE
GEOMETRY	BELOW	CHEMISTRY	SAME
MEASUREMENT	BELOW	PHYSICS	SAME
PROPORTIONALITY	BELOW		

1

Shade in $^{5}/_{8}$ of the unit squares in the grid.



Item 1

International Average - 52

2

A car has a fuel tank that holds 35 L of fuel. The car consumes 7.5 L of fuel for each 100 km driven. A trip of 250 km was started with a full tank of fuel. How much fuel remained in the tank at the end of the trip?

A. 16.25 L

B. 17.65 L

C. 18.75 L

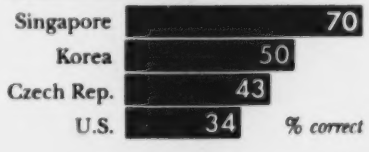
D. 23.75 L

Improving Thoughtful Problem Solving in Mathematics

In this age of information and technology, society's expanding use of data makes it imperative for all citizens to have the facility to reason using quantities. It is in this area of reasoning that U.S. eighth graders often fall behind their counterparts in top-performing countries, in particular, Singapore, Korea, Japan, and Czech Republic.

U.S. students tend to solve multi-step problems as though they involved single-step procedures. For example, in Item 1, about one-fourth of the U.S. eighth graders shaded in 5 squares, presumably because they did not account for the fact that the grid had 24 rather than 8 squares. In Item 2, the most prevalent mistake—made by one-third of the U.S. students—was to select the amount of fuel used on the trip (option C) rather than the amount of fuel remaining in the tank.

Item 2



(data not available for Japan)
International Average - 39

Item 3 was difficult for students in all of the countries. Still, nearly half of the U.S. eighth graders selected the distance traveled by the ball if it only traveled downward, but did not travel back up into the air between bounces (option A).

It is unclear why U.S. students seem to use single-step strategies to solve such problems. This could be due to a less-than-thoughtful approach to solving the problems, an inability to deal with more than one condition in a context, or poorly developed reading skills. The tendency was present in items across all content areas.

3

A rubber ball rebounds to half the height it drops. If the ball is dropped from a rooftop 18 m above the ground, what is the total distance traveled by the time it hits the ground the third time?

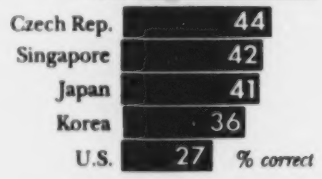
A. 31.5 m

B. 40.5 m

C. 45 m

D. 63 m

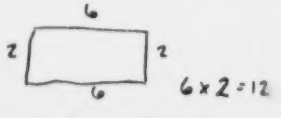
Item 3



International Average - 34

4

The length of a rectangle is 6 cm, and its perimeter is 16 cm. What is the area of the rectangle in square centimeters?



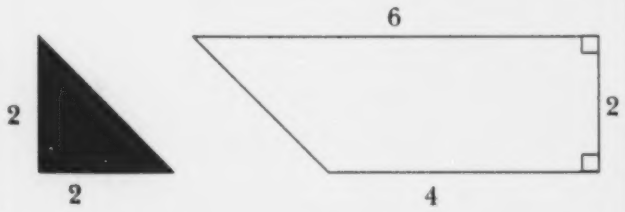
Answer: 12

Item 4

International Average - 40

14

5



How many triangles of the shape and size of the shaded triangle can the trapezoid above be divided into?

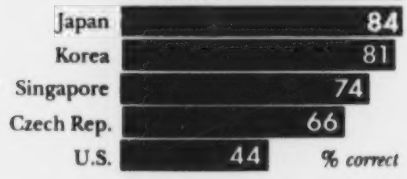
A. Three

B. Four

C. Five

D. Six

Item 5



International Average - 53

6

A straight line on a graph passes through the points (3,2) and (4,4). Which of these points also lies on the line?

A. (1,1)

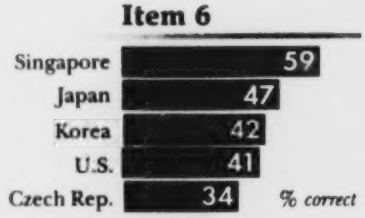
B. (2,4)

C. (5,6)

D. (6,3)

E. (6,5)

Item 6



International Average - 41

TIMSS found that the content of U.S. mathematics classes is not as advanced as in the top-performing countries, and this is reinforced by the achievement results. When the concepts were more specialized, such as in Measurement and Geometry, U.S. eighth-grade students had particular difficulty. For example, Items 4 and 5 required understanding of important concepts in perimeter and area and of the properties of rectangles and triangles. Item 6 indicates that students also may have insufficient understanding of some concepts in Analytic Geometry.

The importance of extending and creating patterns is stressed in the NCTM *Curriculum and Evaluation Standards for School Mathematics*[1] (see *TIMSS as a Starting Point to Examine Teaching* for excerpts from the NCTM standards). The results on several TIMSS items, including Item 7, suggest that U.S. eighth graders could use more emphasis in this area.

Students also had difficulty with more traditional algebra items, such as those that required simplifying, evaluating, and writing expressions. For example, about half of the U.S. students were not successful in identifying the correct expression to represent the number of Clarissa's hats (Item 8).

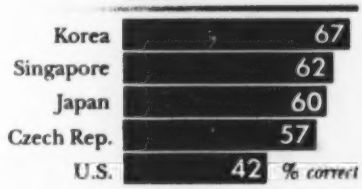
7

The numbers in the sequence 2, 7, 12, 17, 22, ... increase by fives. The numbers in the sequence 3, 10, 17, 24, 31, ... increase by sevens. The number 17 occurs in both sequences. If the two sequences are continued, what is the next number that will be seen in both sequences?

27, 32, 37, 42, 47, 52
38, 45, 52

Answer: 52

Item 7



International Average - 45

Item 8

International Average - 47

8

Juan has 5 fewer hats than Maria, and Clarissa has 3 times as many hats as Juan. If Maria has n hats, which of these represents the number of hats that Clarissa has?

A. $5 - 3n$

B. $3n$

C. $n - 5$

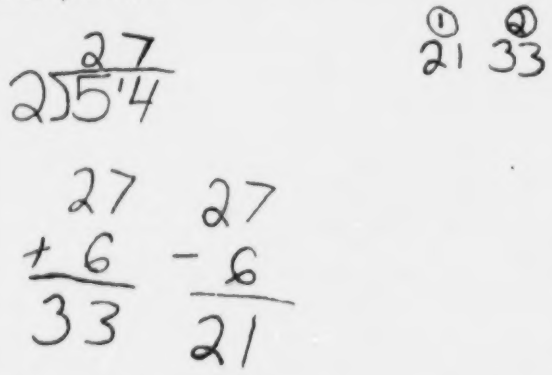
D. $3n - 5$

E. $3(n-5)$

[1] National Council of Teachers of Mathematics. *Curriculum and Evaluation Standards for School Mathematics*. Reston, VA: National Council of Teachers of Mathematics, 1989.

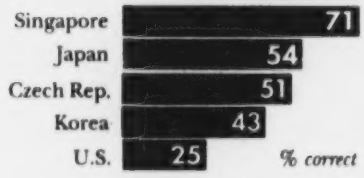
9

There are 54 kilograms of apples in two boxes. The second box of apples weighs 12 kilograms more than the first. How many kilograms of apples are in each box? Show your work.



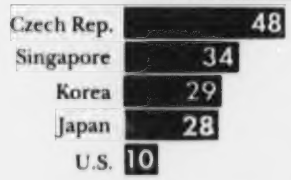
An algebraic equation with an unknown variable could have been used to solve Item 9, although only about 10 percent of the U.S. eighth graders used this approach compared to nearly one-half of the eight graders in Czech Republic. Most of the U.S. students used basic operations but were unsuccessful in providing a correct solution. Regardless of the approach used, just 25 percent of the U.S. eighth graders answered this item correctly compared with 71 percent of those in Singapore.

Item 9



International Average - 32

Percent of Students Using Equation



International Average - 17

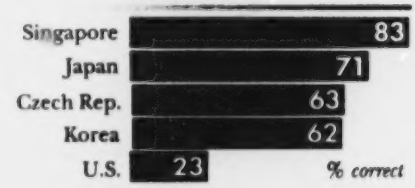
Items 10, 11, and 12 illustrate a range of TIMSS items involving proportionality. All were very difficult for U.S. eighth graders, highlighting the need for further work on this important kind of mathematical reasoning.

10

Peter bought 70 items and Sue bought 90 items. Each item cost the same and the items cost $800 altogether. How much did Sue pay?

Answer: Sue paid 450

Item 10



International Average - 38

11

The table shows the values of x and y, where x is proportional to y.

x	3	6	P
y	7	Q	35

What are the values of P and Q?

A. $P = 14$ and $Q = 31$

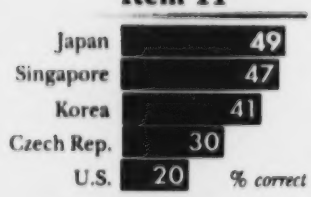
B. $P = 10$ and $Q = 14$

C. $P = 10$ and $Q = 31$

D. $P = 14$ and $Q = 15$

(E.) $P = 15$ and $Q = 14$

Item 11



International Average - 25

12

Two boxes of square-shaped cardboard pieces are available to make a larger pattern. There are 4 small squares in each piece.

All pieces in Box 1 look like

All pieces in Box 2 look like

In the required pattern, for every piece from Box 2 there are 2 pieces from Box 1.

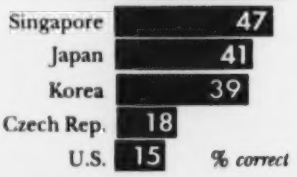
(a) If 60 pieces from Box 2 are used in the required pattern, how many pieces will be needed altogether?

Answer: 180

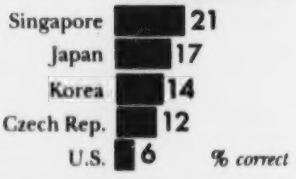
(b) What fraction of the small squares in the required pattern will be black?

Answer: 1/3

Item 12-a



Item 12-b



Taken separately and together, the TIMSS items can reveal considerable information about students' understanding of mathematics and their ability to engage in mathematical reasoning across various content areas. How would students in your classroom, school, district, and state perform on these items?

19

Improving Scientific Understanding

The overall science achievement of U.S. eighth graders, while above the international average, is still far from being the best in the world. This is particularly true in the physical sciences, where U.S. students perform well below their counterparts in Singapore, Japan, Korea, and Czech Republic.

For example, the majority of U.S. eighth graders did not demonstrate a basic understanding of chemical properties or the classification of matter. Item 13 shows that only 27 percent of U.S. students identified oxygen as the gas required for combustion, with 39 percent of the students indicating nitrogen instead. About half of the U.S. students did not distinguish between solutions and separable heterogeneous mixtures as shown in Item 14.

13

Which gas could cause a glowing splint to burst into flame?

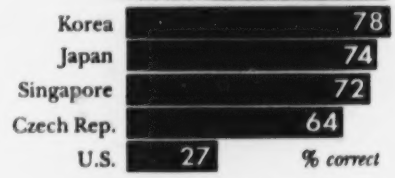
A. Neon

(B.) Oxygen

C. Nitrogen

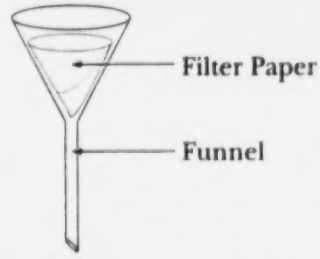
D. Carbon dioxide

Item 13



International Average - 51

14



Filtration using the equipment shown can be used to separate which materials?

A. A solution of copper sulfate and water

B. A solution of sodium chloride and water

C. A mixture of alcohol and water

(D.) A mixture of mud and water

E. A mixture of sand and sawdust

Item 14

International Average - 53

20

15

Which is NOT an example of a chemical change?

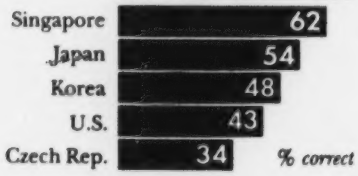
A. Boiling water

B. Rusting iron

C. Burning wood

D. Baking bread

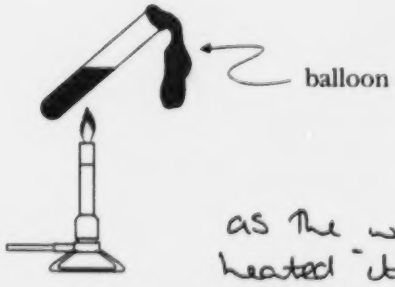
Item 15



International Average - 31

16

The water in a tube is heated, as shown in the diagram. As the water is heated, the balloon increases in size. Explain why.



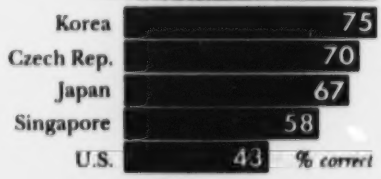
as the water is heated it will evaporate and the steam will go up into the ballon making it raise

The distinction between chemical and physical transformations is also a difficult concept for many U.S. students to grasp (see Item 15).

By the eighth grade, students in the top-performing countries in science are developing a grasp of physics concepts and are able to apply these to solve problems and provide explanations. While the majority of U.S. students demonstrate a basic understanding of many physics concepts, fewer students are able to apply these scientific principles to solve the more complicated TIMSS science problems. In general, this is true across all areas of physics covered by the TIMSS test, including physical properties and transformations, forces and motion, and energy concepts.

Fewer than half of U.S. students could apply concepts of evaporation and vapor pressure in Item 16.

Item 16

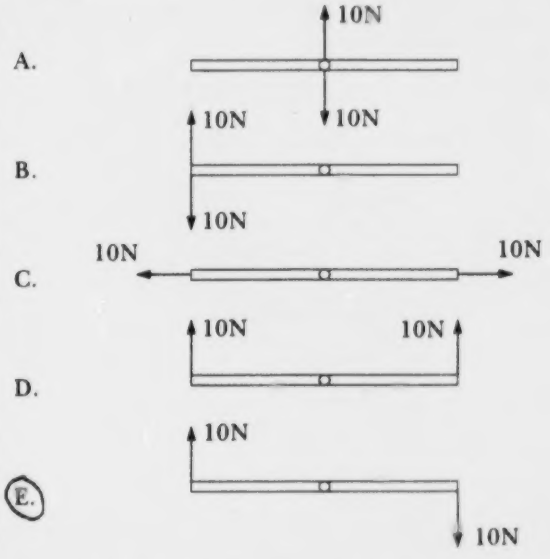


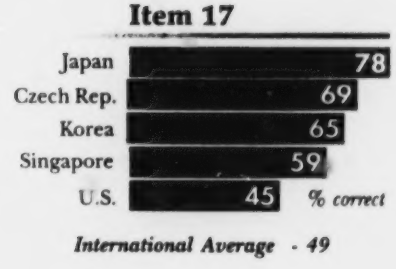
International Average - 58

U.S. students also had difficulty applying knowledge of mechanical forces in Item 17, with nearly half indicating a lack of understanding of balanced forces by selecting options in which no movement of the rod would occur (A, B, and C). For Item 18, fewer than half of the U.S. students demonstrated this knowledge of the nature of visible light and its interaction with matter to produce colors.

17

A uniform rod is pivoted at its center. It is acted on by two forces in the same plane. Each force has the same size, equal to 10 N (newtons). In which case is there a turning effect?





18

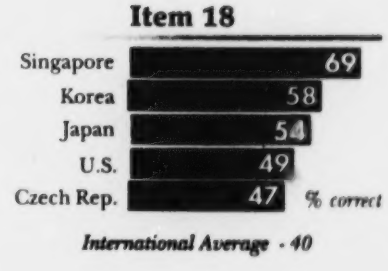
When white light shines on Peter's shirt, the shirt looks blue. Why does the shirt look blue?

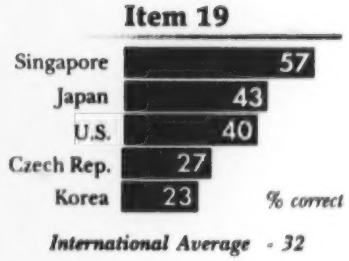
A. It absorbs all the white light and turns most of it into blue light.

(B.) It reflects the blue part of the light and absorbs most of the rest.

C. It absorbs only the blue part of the light.

D. It gives off its own blue light.



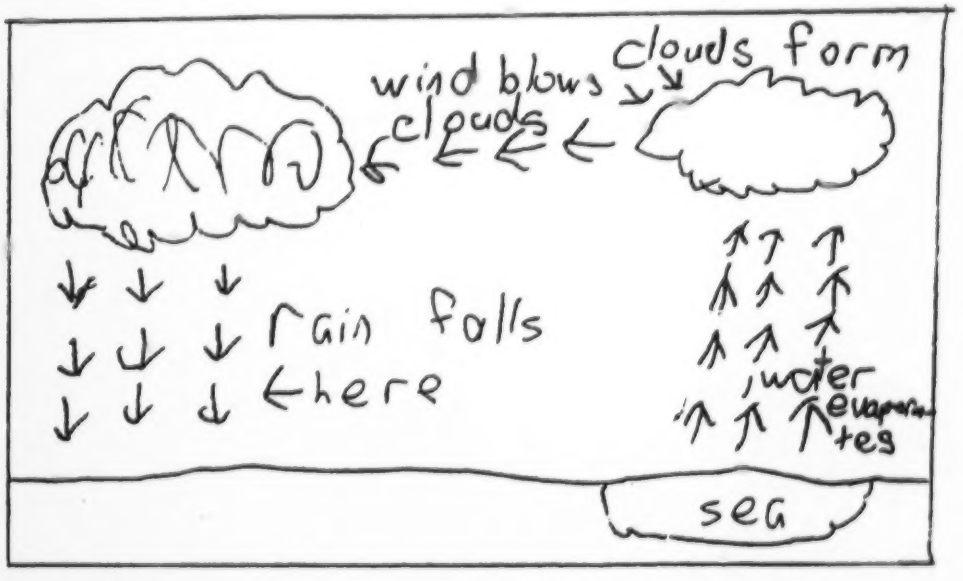


While U.S. performance compares more favorably with that of top-performing countries in the Earth, Life, and Environmental Sciences than it does in Physics and Chemistry, there is still room for improvement in some areas.

Some items which required knowledge of earth features and processes were quite challenging for U.S. students. In Item 19, two-fifths of the eighth graders in the United States, compared with the nearly three-fifths in Singapore, indicated all three steps in the water cycle—evaporation, transportation, and precipitation.

19

Draw a diagram to show how the water that falls as rain in one place may come from another place that is far away.

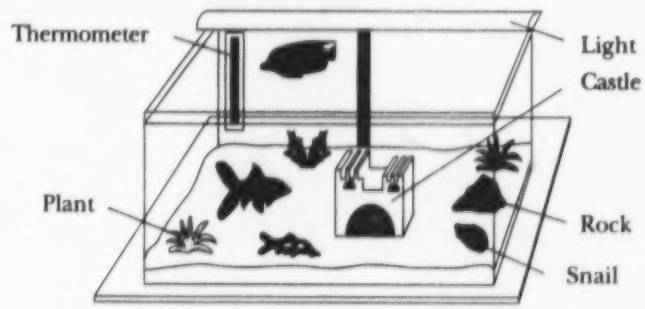


23

U.S. students did relatively well on items involving basic knowledge of human biology. Yet, lower performance on items covering the diversity, organization, structure, and interaction of other plant and animal life forms suggests more focus is needed in these areas in U.S. science classes. Even though more than 60 percent of the U.S. students could explain the importance of plants in aquarium ecosystems (Item 20a), nearly all students in Singapore could do so. Only 26 percent of the U.S. students could explain the importance of light. Of these, fewer than 10 percent mentioned energy or photosynthesis, compared with more than 70 percent in Singapore (Item 20b).

20

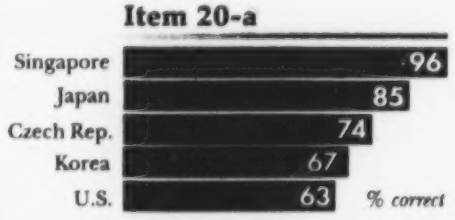
In the picture of an aquarium, six items are labeled.

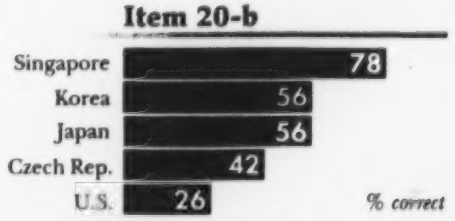


Explain why each of the following is important in maintaining the ecosystem in the aquarium.

(a) the plant to give off oxygen and take in carbon dioxide which the animals breath out

(b) the light to help the plant make photosynthesis and make its own food

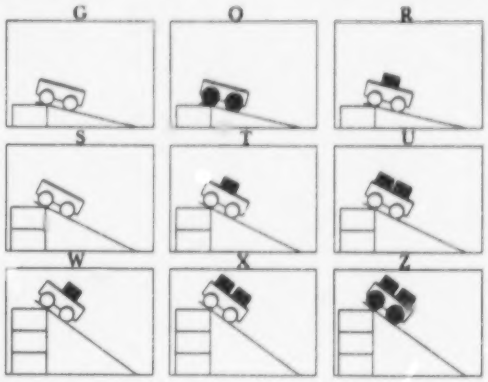




24

21

The diagrams show different trials Abdul carried out with carts having different-sized wheels. He started them from different heights, and the blocks he put in them were of equal mass.



He wants to test this idea: The heavier a cart is, the greater its speed at the bottom of a ramp. Which three trials should he compare ?

A. G, T, and X

B. O, T, and Z

C. R, U, and Z

(D) S, T, and U

E. S, W, and X

As emphasized by the American Association for the Advancement of Science (AAAS) in *Benchmarks for Science Literacy*[2] and the National Academy of Sciences' *National Science Education Standards*[3] students should be actively engaged in scientific inquiry by designing and conducting investigations. Several of the TIMSS science items reveal that students in the United States need more emphasis on the skills required in this area. In Item 21, only 32 percent of the U.S. students recognized the need to control other variables when conducting an experiment investigating the effect of mass.

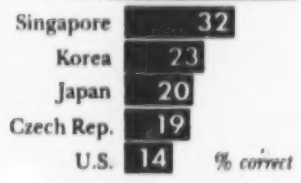
Item 21

[2] American Association for the Advancement of Science. *Benchmarks for Science Literacy: Project 2061.* New York: Oxford University Press, 1993.

[3] National Academy of Sciences. National Science Education Standards. Washington, DC: National Academy Press, 1995.

Designing and communicating an investigation of the effect of exercise on heart rate (Item 22) was quite difficult for students in most countries. Nevertheless, nearly one-third of the students in Singapore, compared with only 14 percent in the United States, describe a procedure that included using a timer to make measurements of pulse before and after exercise.

Item 22



International Average - 14

22

Suppose you want to investigate how the human heart rate changes with changes in activity. What materials would you use, and what procedures would you follow?

materials: stopwatch

procedures: I would have a person sit and then take their pulse.

I would have the person walk, then take their pulse again.

Finally, I would have the person run and take their pulse.

Each time I took their pulse I would time how many times per minute their heart was beating

Because advances in science and technology will form the basis for success in the global community of the 21st century, performance by U.S. students that is just above average may not be good enough to ensure the economic health of our nation. How would students in your classroom, school, district, or state perform on these or similar TIMSS items?

School Contexts for Learning

The TIMSS questionnaire data collected in conjunction with the testing provide another lens through which to view the achievement results. Each TIMSS student completed a questionnaire about his or her attitudes toward mathematics and science, parental expectations, out-of-school experiences, and classroom activities. The mathematics and science teachers of each TIMSS student also completed a questionnaire especially geared toward the teaching of mathematics and science. The teacher questionnaire asked about teachers' preparation, instructional practices, and textbook usage, and their views on current issues in mathematics and science education. The school principal of each school in TIMSS completed a questionnaire regarding school characteristics, resources, course offerings, and the community. Countries also provided extensive information about their educational systems, with a specific focus on mathematics and science education, curricula, textbooks, and assessment. This information has been analyzed and published in a compendium titled *National Contexts for Mathematics and Science Education: An Encyclopedia of the Education Systems Participating in TIMSS*[3] available from the University of British Columbia, Faculty of Education.

The data collected from students, teachers, and school principals, as well as the system-level information collected from the participating countries, provide an abundance of information about similarities and differences in educational practices between the United States and other countries. Initial findings based on these data are available in the following publications found in this module of the TIMSS Resource Kit: *Mathematics Achievement in the Middle School Years, Science Achievement in the Middle School Years,* and *Pursuing Excellence: A Study of Eighth-Grade Mathematics and Science Teaching, Learning, Curriculum, and Achievement in International Context.* For example:

- Similar to the United States, most countries report that four years of post-secondary education and practice in

[3] Robitaille, D.F. (Ed.). *National Contexts for Mathematics and Science Education: An Encyclopedia of the Education Systems Participating in TIMSS.* Vancouver, Canada: Pacific Educational Press, 1997.

teaching are required for teacher certification. However, in contrast to the United States, most countries report that some form of examination also is required.

- Different from the United States, the curriculum in most of the TIMSS countries is determined by national authorities. Consequently, textbooks are prepared in accordance with the course of study, and classes are conducted using these textbooks.
- U.S. eighth graders spend more hours in mathematics and science classes than their counterparts in many countries, so the lack of sufficient class time is not the reason why U.S. students perform below the levels achieved by the top-performing countries.
- Eighth graders in most countries typically report studying mathematics for roughly an hour each day outside of school and science for somewhat less than that. However, in comparison with most countries, students in the United States spend more in-class time working on their homework.
- In mathematics, all (or nearly all) students in five of the six top-performing countries follow the same course of study through the eighth grade. In Singapore, there are two courses of study. Thus, in general, all students are expected to achieve the same curriculum. In the United States principals report from two to six courses of study, with the average being three.
- In almost half of the TIMSS countries, eighth-grade science is taught not as an integrated subject, but as individual science subjects (Biology, Chemistry, etc.). In these countries, there are two, three, or even four different science courses available for eighth graders.
- Interestingly, teenagers appear to be much the same around the world. Eighth graders in all countries reported spending a fair amount of out-of-school time on non-academic activities. Most frequently, students reported watching one or two hours of television each day, as well as spending several hours playing or talking with friends, and nearly two hours playing sports. (Of course, for teenagers, these activities often occur simultaneously, such as watching television and talking with friends on the telephone.)

Because there are various pathways to academic excellence, it is informative to consider the contexts for learning in other countries, and how various factors can interact. No single factor in isolation from others should be regarded as the answer to improving students' achievement in a particular state, district, school, or classroom, but the TIMSS results do provide a way for states and districts to examine their own educational policies and practices from an international perspective.

Just as achievement information can provide information vital to improving curricula and teaching emphases, information about teachers' preparation, the activities they use in their classrooms, and the resources they rely upon in their teaching can provide insights into the best ways to improve instructional practices. Similarly, information about students' background and attitudes can suggest ways of stimulating students' willingness to study and learn.

Effective education is key to improving the situations of both individuals and societies, and it is very important to examine the implications of alternative approaches to learning. The TIMSS results provide an "educational laboratory" within which the strengths and weaknesses of educational practices can be assessed.

Conclusion

International studies of educational achievement and its contexts better equip policymakers to study their own approaches to education. For example, the overall achievement standings for the United States on TIMSS indicate that our nation needs to improve our education system if we want our children to achieve on par with the best in the world. Looking at performance on individual test questions reveals strengths, but also a number of weaknesses, regarding U.S. students' understanding of particular concepts in mathematics and science.

Learning that other countries have higher levels of educational achievement than the United States can show what is possible and serve as an impetus to making necessary changes. In his recent State of the Union address, President Clinton challenged every community and state to adopt national standards of excellence in education. He called for voluntary administration of individual-level national tests in reading at grade 4 and mathematics at grade 8 to monitor progress toward these standards. Beginning in 1999, the tests will provide an annual indication of a student's overall proficiency that can be reported to parents and teachers. The reading and mathematics tests will be comparable to the NAEP assessments in those subjects, and at the eighth-grade level, the national test also will be comparable to the mathematics section of TIMSS. For more information about the new national tests, contact the U.S. Department of Education at (202) 219-2042, or visit the test's Web site at http://www.ed.gov/nationaltests.

Studying the various approaches to education used in the different countries also provides important grist for the mill of systemic reform. TIMSS data are a measure against which states and districts can examine current pedagogy, curriculum, and assessment practices. For example, the data can raise issues about the following areas:

- the content and rigor of the curriculum;
- the expectations for high academic achievement for all students;
- the preparation of teachers and the quality of the support they receive;
- the adequacy of instructional materials and resources;
- the quality of classroom instruction;
- the amount of time students spend studying mathematics and science;
- the types of academic support students receive outside of school; and
- the consistency between assessment approaches and the goals of improving students' achievement.

Because they can support or challenge existing notions, insights about educational practices in other countries can fuel the debate about needed improvements and how best to go about implementing them. The TIMSS results indicate many pathways to excellence, and the alternatives represented by the participating countries can serve to stimulate an examination of what approaches are likely to be most effective in your particular classroom, school, district, or state.

Ordering the TIMSS Reports for Third- and Fourth-Grade Students

Mathematics Achievement in the Primary School Years: IEA's Third International Mathematics and Science Study, $20.00 (prepaid).

Science Achievement in the Primary School Years: IEA's Third International Mathematics and Science, $20.00 (prepaid).

These two reports provide international comparative results in mathematics and science achievement, respectively, for third and fourth graders in 26 countries. The information corresponds to that presented in the middle school reports. Because the 26 countries included in the primary school reports represent a subset of the countries that participated at the seventh- and eighth-grade levels, comparisons across grades are possible.

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